PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :
B60K 6/04, B60L 11/12 // H02K 16/02

A1

(11) International Publication Number: WO 00/34066

(43) International Publication Date: 15 June 2000 (15.06.00)

(21) International Application Number: PCT/SE99/02276

(22) International Filing Date: 7 December 1999 (07.12.99)

(30) Priority Data:
9804261-7 8 December 1998 (08.12.98) SE

(71) Applicant (*for all designated States except US*): ABB AB [SE/SE]; S-721 83 Västerås (SE).

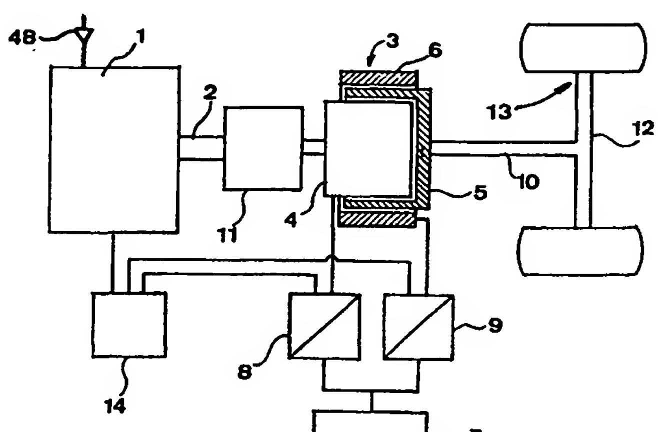
(72) Inventors; and
(75) Inventors/Applicants (*for US only*): BERG, Niclas [SE/SE]; N. Allégatan 28, S-722 19 Västerås (SE). BÄCKSTRÖM, Thomas [SE/SE]; Ljungvägen 4, S-746 51 Bålsta (SE). ERIKSSON, Sture [SE/SE]; Lindmätargatan 10, S-723 46 Västerås (SE). MALMQVIST, Anders [SE/SE]; Sköldvägen 9 A, S-187 36 Täby (SE). SADARANGANI, Chandur [GB/SE]; Höggatan 5, S-724 66 Västerås (SE). ÖSTLUND, Stefan [SE/SE]; Frejgatan 6, S-114 20 Stockholm (SE).

(74) Agents: BJERKÉN, Håkan et al.; Bjerkéns Patentbyrå KB, P.O. Box 1274, S-801 37 Gävle (SE).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ (Utility model), DE (Utility model), DK (Utility model), DM, EE, ES, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK (Utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Swedish).

(54) Title: A HYBRID DRIVE DEVICE AND A WHEELED VEHICLE PROVIDED WITH A HYBRID DRIVE DEVICE



(57) Abstract

A hybrid drive device has an internal combustion engine (1), an energy converter (3) adapted to co-operate with an output shaft (2) of the internal combustion engine and which comprises an electric machine having a first (4) and a second (5) rotor, which are arranged to co-operate by transmitting power through magnetism with each other and may rotate with different numbers of revolutions, one (4) of which is provided with one or several windings. A power source (7) is adapted to exchange electrical energy with the windings through the alternating voltage in the windings. A unit (6) is adapted to be able to influence the torque of the drive shaft (10) out from the energy converter without changing the number of revolutions of this shaft or changing the number of revolutions of the output shaft (2) of the internal combustion engine.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

A HYBRID DRIVE DEVICE AND A WHEELED VEHICLE PROVIDED WITH A HYBRID DRIVE DEVICE

FIELD OF THE INVENTION AND PRIOR ART

The present invention relates to a hybrid drive device comprising an internal combustion engine, an energy converter adapted to co-operate with an output shaft of the internal combustion engine and which comprises at least one electric machine having a first and a second rotor, which are adapted to co-operate with each other by transmitting power through magnetism and may rotate with different numbers of revolutions, at least one of which being provided with one or a plurality of windings, and a power source adapted to exchange electrical energy with said windings through an alternating voltage in said windings for a co-operation of the rotors by transmitting power through magnetism, as well as a wheeled vehicle provided with such a hybrid drive device.

Such hybrid drive devices may be used in all conceivable situations, where there is a desire to be able to co-ordinate the energy supply through an internal combustion engine and the energy supply by way of electricity for energy generation and driving a drive shaft. It may be a question of industrial processes, in which there may be a desire to drive certain machines, transport devices or the like sometimes through an internal combustion engine sometimes through an electric power source and sometimes through both of them. In different situations of operation energy may then be led in different directions between the output shaft of the internal combustion engine, the

energy converter and said power source for exchanging electrical energy, and it may for example well be so that the internal combustion engine in some situations of operation charges said power source through the energy converter, and this gives then accordingly no addition at all to the energy for driving the drive shaft.

The power source may be of various types, such as an electric battery or ultra capacitors, but neither does it have to be an energy buffer, but it may be formed by an auxiliary engine. It is also well conceivable that the power source is formed by the general electric network.

A particularly interesting field of use for a hybrid drive device of this type is for driving wheeled vehicles, and this particular application will therefore hereinafter be described for illuminating the invention and the problem to be solved thereby, but this is not at all to be interpreted as limiting the scope of the invention.

Hybrid drive devices for vehicles are used for utilizing the advantage of internal combustion engines with respect to the possibility to carry fuel in the vehicle lasting for a long driving distance and the advantage of battery operation with respect to absence of emissions (exhaust gases) and indulgence with respect to the environment. Thus, it is advantageous when driving on a highway to generally drive the vehicle through the internal combustion engine while charging the power source (the battery or the batteries) and possibly sometimes, such as when overtaking, when going uphill or the like, with an energy addition from the power source, so as to have a sufficient amount of energy stored in the battery when driving in city traffic for being able to drive the vehicle there through electric driving alone. The distribution of the load between the internal combustion engine and the battery may then be controlled according to determined criteria for obtaining an optimum such distribution

with respect to environmental demands and with respect to operation time and operation characteristics of the hybrid drive device.

Hybrid drive devices of this type for wheeled vehicles are known through for example DE-A1-41 18 678 and US-A-3 796 278.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a hybrid drive device of the type defined in the introduction, which enables an improved utilization of the possibility to combine the internal combustion engine and said power source through the energy converter with respect to such hybrid drive devices already known, especially by obtaining a large freedom to adapt the different energy flux with respect to magnitude and direction to the operation conditions prevailing, such as a possibility to let the internal combustion engine operate at given optimum numbers of revolutions and torques.

This object is according to the invention obtained by providing the energy converter of a hybrid drive device of the type defined in the introduction with a unit adapted to be able to influence the torque of a drive shaft out from the energy converter without changing the number of revolutions of this shaft or changing the number of revolutions of the output shaft of the internal combustion engine, and by the fact that the device comprises a regulating arrangement adapted to co-ordinate control of energy flows to and from the internal combustion engine, the electric machine and said unit.

It will hereby be possible to obtain a high efficiency of the internal combustion engine, since the existence of said unit in combination with the electrical energy converter gives an increased freedom of letting the internal combustion engine operate at an optimum number of revolutions and torque, which also

results in a possibility to keep the emissions from the internal combustion engine at a comparatively low level. Thus, it will be possible to influence the torque of the drive shaft without changing the number of revolutions of this shaft, which makes it possible to maintain an unchanged number of revolutions if desired of the output shaft of the internal combustion engine inspite of changing the torque of said drive shaft. This may be achieved by appropriate controlling of the energy converter (the electric machine thereof). Although the hybrid drive device according to the invention is in fact a parallel hybrid system a series hybrid function is obtained in this way in the sense that the number of revolutions and the torque of the internal combustion engine are not determined by the number of revolutions and the torque of said drive shaft – in the case of a wheeled vehicle the wheel axle of this vehicle.

According to preferred embodiment of the invention said unit comprises a second electric machine having at least a rotor connected to said drive shaft and a stator, that at least one of the stator and the rotor of the second electric machine is provided with windings and that the power source is adapted to exchange electric energy with the windings last mentioned through an alternating voltage in said windings for co-operation of the rotor and the stator of the second machine by transmitting power through magnetism and thereby of the stator and said drive shaft out from the energy converter. By arranging such a second electric machine of the energy converter it will be possible through the energy supply to the winding of this machine to give a torque contribution to said drive shaft completely independent of the number of revolutions of the output shaft of the internal combustion engine. Thus, the first machine may be controlled completely independent of the second machine for enabling a desired number of revolutions of the output shaft of the internal combustion engine at a given number of revolutions of the drive shaft, which may be imposed by the number of revolutions of a wheel axle connected to the drive

shaft, and the possible number of revolutions of the output shaft of the internal combustion engine may be varied by controlling the first electric machine, and the torque on the drive shaft may at the same time be varied completely independent thereof through controlling the energy supply to said second electric machine. Accordingly, the number of revolutions of the internal combustion engine may be controlled by means of the electric frequency fed to the rotor windings of the first electric machine. Thus, the power of the drive shaft in this device will consist of power supplied through the internal combustion engine, power supplied through the rotor windings of the first electric machine as well as power supplied through the winding of the second electric machine, which gives many possibilities to combine these three components for obtaining an optimum operation of the device. The powers in said windings may in some operation cases be negative, i.e. energy is fed therefrom to said power source or energy source. Another advantage is that this device has a threefold redundancy by the possibility to electrical operation through the stator, electrical operation through the rotor windings and internal combustion engine operation, for example by interlocking the two rotors of the first electric machine.

According to another preferred embodiment of the invention the device comprises an arrangement for interlocking pieces of the device movable with respect to each other or such pieces and a stationary frame with respect to rotation, and it also comprises a control arrangement adapted to control the locking arrangement to assume a position interlocking said pieces or releasing said pieces with respect to each other depending upon the operation condition of the device. Hereby one or both electric machines or the internal combustion engine may be turned off when there is a need to do so and the drive device may still function and/or possibly negative consequences of turning one of the electric machines or the internal combustion engine off may be avoided.

According to another preferred embodiment of the invention constituting a further development of the embodiment just mentioned the locking arrangement comprises members adapted to enable interlocking of the output shaft of the internal combustion engine and said drive shaft, in which this preferably takes place by arranging the locking members to interlock said first and second rotor of the energy converter with respect to rotation. It will thereby be possible to drive the drive shaft only through the internal combustion engine when desired, but it is then also possible to have only the first electric machine turned off, but power is supplied to the drive shaft through the stator winding upon need.

According to another preferred embodiment of the invention the control arrangement is adapted to make the position of said locking members dependent upon whether energy exchange between said rotor windings and the power source interacting therewith takes place and automatically interrupt the interlocking upon establishing of an electric current between the power source and the rotor windings and activate the interlocking when such a current disappears. A passive operation security is hereby obtained by the fact that the internal combustion engine will be directly coupled to the drive shaft would the possibility to energy supply through the power source to the rotor windings cease, which may take place in the case of a power source in the form of a battery and a converter arranged between the battery and the rotor winding should the function of the converter disappear.

According to another preferred embodiment of the invention the locking arrangement comprises members adapted to enable a locking of the output shaft of the internal combustion engine with respect to rotation with respect to a stationary frame, and the control arrangement is adapted to control the locking members last mentioned to establish such a locking as long as

the internal combustion engine is turned off. The output shaft of the internal combustion engine may when this is turned off in this way be secured for managing for example a pure electrical operation case through the rotor windings in which the compression of the internal combustion engine would not be able to withstand the reaction torque from the load onto the drive shaft, such as in the vehicle case through the wheel axle when driving.

According to another preferred embodiment of the invention the first and the second rotor are arranged substantially concentrically with the first one received in a space enclosed by the second one for generating substantially radially magnetic flux therebetween, the shaft of the second rotor is hollow and adapted to receive the shaft of the first rotor adapted to project through and out past the shaft of the second rotor, slip rings for transmitting electricity between said power source and the windings of the first rotor are arranged on the part of the shaft of the first rotor projecting out of the shaft of the second rotor opposite to said space, and the shaft of the first rotor is hollow for housing conductors for electrically connecting the slip rings to the windings of the first rotor. It will hereby inspite of the design of the electric machine as a so called radial machine with the rotor provided with windings surrounded by the second rotor with the advantages of such a machine from the power transmitting point of view be very simple to achieve connection of the windings of the first rotor to electricity.

According to another preferred embodiment of the invention the second rotor of the first electric machine forms the rotor for the second electric machine, and the stator is arranged radially outside the second rotor for acting thereupon through substantially radial magnetic flux. A so called double radial machine has a number of advantages, among which the following may be mentioned: it has a compact design and may be housed within a conventional gearbox of a wheeled vehicle thanks to the short

axial length. Bearings in the energy converter may be avoided if bearings of the internal combustion engine and an existing gearbox are utilized. Slip rings may be housed in the hub of the rotating winding if desired. The axial forces in the energy converter will be low.

According to another preferred embodiment of the invention the second rotor of the first electric machine forms the rotor for the second electric machine, and the stator is adapted to co-operate with surfaces of the second rotor directed substantially axially in the direction of the axis of rotation of the second rotor through a substantially axially magnetic flow between the stator and this rotor. A so called radial axial machine with interalia the following advantages is hereby obtained. Since it is possible to use the first rotor provided with windings and connected to the output shaft of the internal combustion engine as flywheel in a hybrid drive device of this type a better flywheel action is obtained for this design thanks to the possibility of a larger diameter of the first rotor. Another advantage is that the two magnetic circuits are separated. The combination of radial and axial machine is interesting, since a requirement of operation without hitting the ground results in demands for a minimum diameter, while there is space in the axial direction.

According to another preferred embodiment of the invention, which constitutes a further development of the embodiment last mentioned, the stator and the second rotor are arranged to co-operate by transmitting power through magnetism through substantially axial air gaps between surfaces thereof, and the number of such axial air gaps is 2n, in which n is an integer ≥ 1. A balancing of the axial forces created by each air gap and which will attract the rotor to the stator is hereby obtained, so that powerful axial bearings, which otherwise would be required for absorbing these axial forces, may be omitted.

According to another preferred embodiment of the invention the second rotor has a plurality of rotor discs separated axially and the stator has a plurality of stator pieces separated axially, and the stator pieces and the rotor discs are arranged alternatingly in the axial direction for transmitting power through magnetism therebetween. It will in this way be possible to obtain very high forces and thereby torques on the second rotor and thereby on the drive shaft through an addition of the forces from each couple of surfaces of the stator piece and the rotor disc at the respective axial air gap.

According to another preferred embodiment of the invention the stator is adapted to act upon surfaces of the second rotor directed substantially axially from the axially opposite direction to the influence of the first rotor on the second rotor through magnetic flux directed substantially axially. A so called double axial machine is hereby obtained, which interalia has the advantage of making smaller air gaps possible, which leads to a higher possible torque for a given volume. Furthermore, the diameter of the fly wheel casing may be utilized to a maximum when the rotor provided with a winding is utilized as fly wheel, which gives a better fly wheel function.

According to another preferred embodiment of the invention the second electric machine is a reluctance machine with poles magnetically imprinted on the rotor thereof for increasing the reactance between the stator and the rotor at the poles with respect to what is the case between these poles. The advantage with respect to a permanent magnet machine, i.e. the arrangement of permanent magnets on the rotor for co-operating with the windings of the stator instead, that the iron losses are eliminated when the second machine is disactivated is hereby obtained, i.e. when there is a desire to only drive the drive shaft through the internal combustion engine or it is selected to have an electrical operation with only the first machine activated. Such a machine has an even higher efficiency and the rotor

thereof gets a simple construction. Another advantage of a reluctance machine with respect to a permanent magnet machine is that no rotor position detectors are needed in the reluctance machine case, since the rotor will all the time be adapted to the stator.

According to a preferred embodiment of the invention, which constitutes a further development of the embodiment last mentioned, the device comprises means for increasing the relationship between the reactance for a magnetic flux through the stator, to a pole of the rotor being magnetically imprinted and back to the stator through an adjacent pole of the rotor being magnetically imprinted with respect to the reactance for a magnetic flux through the stator, to a portion between poles of the rotor being magnetically imprinted and then back to the stator, by which the torque possible to apply on the rotor and thereby the drive shaft through the stator windings may be increased.

According to another preferred embodiment of the invention said means are formed by pieces of a material arranged to function as a barrier for magnetic flux laid in the rotor substantially at the location or the portions between two adjacent poles being magnetically imprinted so as to reduce the reactance for magnetic flux between the stator and the rotor through said portions. The torque possible to transfer to the rotor of the second machine is by this efficiently increased.

According to another preferred embodiment of the invention the second rotor has permanent magnets on the opposite side thereof to the poles magnetically imprinted for co-operation with the windings of the first rotor, and the magnetic imprint on one side of the rotor and the arrangement on the permanent magnets on the opposite side thereof are adapted to each other in such a way that the magnetic flux through the rotor deriving on one hand from the permanent magnets and on the other from the reluctance machine, run in substantially opposite directions

and mainly cancelling each other out. The thickness of the second rotor may hereby be minimized and so costs are saved, since it is only necessary to consider one machine with respect to the saturation in the iron.

According to another preferred embodiment of the invention the first rotor is arranged on an input shaft of the energy converter on the internal combustion engine side, and it comprises members adapted to establish an electric connection between the windings of the first rotor and the power source in parallel with a connection thereof through brushes bearing on slip rings when the output shaft of the internal combustion engine rests. It is hereby ensured that the brushes are not destroyed when the internal combustion engine is not moving, since otherwise circulating currents and brush voltage drop would burn the brushes and/or slip rings when the brushes and slip rings are resting against each other and the device is driven in electric operation.

According to another preferred embodiment of the invention said power source is a direct current source, such as an electric battery, and this is connected to said windings through a converter. Energy exchange may hereby easily take place in a desired way between the windings and the power source and the frequency of an alternating voltage fed to the windings may be varied according to the desire.

According to another preferred embodiment of the invention said unit is a gear having a variable gear change connected to one of the rotors of the energy converter, and this gear and an arrangement for controlling the energy exchange between the power source and the rotor provided with windings are arranged to co-operate. An increase of the torque of the drive shaft is for example hereby obtained by a gear reduction of said gear, which would normally result in a lower number of revolutions of the drive shaft without any change of the number of revolutions

of the output shaft of the internal combustion engine, but for compensating this the first electric machine is then controlled to increase the number of revolutions, so that the number of revolutions of the drive shaft is maintained without changing the number of revolutions of the output shaft of the internal combustion engine.

The invention also relates to different embodiments of the device having different properties of the regulating arrangement defined in the appended dependent claims with advantages being particularly accentuated when using the hybrid drive device in a wheeled vehicle, and these "operation modes" will be described in the detailed description of preferred embodiments of the invention.

The invention also relates to a vehicle such as a wheeled vehicle, a railway vehicle and a ship, equipped with a hybrid drive device according to any of the appended claims directed to such a device. The advantages of utilizing such a device in particular in wheeled vehicles appear from the discussion above and the following description.

Further advantages as well as advantageous features of the invention appear from the other dependent claims and the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

With respect to the appended drawings, below follows a description of preferred embodiments of the invention only cited as examples. In the drawings:

Fig 1 is a simplified view of a hybrid drive device according to a first preferred embodiment of the invention,

Fig 2 is a somewhat more detailed view of the device according to Fig 1,

Fig 3 is a view corresponding to Fig 2 of the device according to Fig 1 in a somewhat modified construction with respect to Fig 2,

Fig 4 is a very schematical view illustrating a section through the energy converter of the device according to Fig 1,

Fig 5 is a power flow diagram for different operation modes of a hybrid drive device of the type according to the invention,

Fig 6 is a radial section through the energy converter of a hybrid drive device according to a second preferred embodiment of the invention with a second machine of the energy converter in the form of a synchronous reluctance machine,

Fig 7 is a detailed view of a part of the rotor of the synchronous reluctance machine according to Fig 6 in a particular embodiment,

Fig 8 is a view corresponding to Fig 7 with a different design of the rotor,

Fig 9 is a view corresponding to Fig 7 illustrating the magnetic flux path in the rotor being the same to both electric machines of the energy converter according to Fig 6,

Fig 10 is a view corresponding to Fig 2 of the energy converter of a hybrid drive device according to a second preferred embodiment of the invention,

Fig 11 is a view corresponding to Fig 10 of the energy converter of a hybrid drive device according to a third preferred embodiment of the invention,

Fig 12 is a view corresponding to Fig 2 of a hybrid drive device according to a fourth preferred embodiment of the invention,

Fig 13 is a view corresponding to Fig 2 of a hybrid drive device according to a fifth preferred embodiment of the invention,

Fig 14 is a simplified view corresponding to Fig 2 of the energy converter of a hybrid drive device according to a sixth preferred embodiment of the invention,

Fig 15 illustrates a part of a rotor disc of the device according to Fig 14,

Fig 16 illustrates a part of the stator of the device according to Fig 14, and

Fig 17 is a view corresponding to Fig 1 of a hybrid drive device according to a sixth preferred embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

The principle of the hybrid drive device according to the invention and how a preferred embodiment of the invention may be constructed is schematically illustrated in Fig 1. The device comprises an internal combustion engine 1 having an output shaft 2, which forms an input shaft of an energy converter 3, which in its turn comprises two electric machines, namely a first electric machine formed by a first rotor 4 connected to said output shaft 2 and a second rotor 5 surrounding this and a second electric machine formed by the second rotor 5 and the stator 6 surrounding the latter. The two parts of the respective electric machine are arranged to co-operate by transmitting power through magnetism with each other. For achieving this the first rotor 4 and the stator are provided with windings, and the device comprises a power source in the form of an electric battery

7, which is connected to said windings through a converter 8, 9 each for converting the direct voltage from the battery into an alternating voltage of the windings or when feeding energy in the opposite direction a conversion of alternating voltage into direct voltage. Energy may also be fed between the converters. Furthermore, the second rotor 5 has permanent magnets arranged internally for co-operation with opposite rotor windings and on the outer side also permanent magnets for co-operation with stator windings. The converters may then for example be arranged to generate a three-phase voltage on said windings, but another phase number is also possible.

The second rotor 5 is connected to a drive shaft 10 out from the energy converter, which in an embodiment according to Fig 2 may receive a reduction of the number of revolutions in a reduction gear 11 and through this transfer the rotation torque thereof to the wheel axle 12 of a wheeled vehicle 13 schematically indicated, such as a passenger car, a lorry or the like. However, a gear 11 may instead, as shown in Fig 1, be arranged between the output shaft of the internal combustion engine and the first rotor, in which this gear normally has the task to change up the number of revolutions of the internal combustion engine for reducing the difference in number of revolutions between the rotors. The gear 11 will in the normal case be located "after" the rotors, as shown in Fig 2, but the gear has in Fig 1 been shown "before" the rotors for illustrating this possibility as well.

The device comprises also a regulating arrangement 14 schematically indicated and adapted to co-ordinate the control of energy flux to or from the internal combustion engine and the two electric machines.

The function of this hybrid drive device and the advantages thereof will be described further below.

It is illustrated a little bit more in detail in Fig 2 what the hybrid drive device operating according to the principle shown in Fig 1 may look like according to a first preferred embodiment of the invention, and the windings 15 and 16 of the first rotor and the stator, respectively, as well as the outer permanent magnets 17 and 18, respectively, arranged on the second rotor appear. It is here shown how slip rings 19 are arranged on the shaft of the first rotor inside the space delimited by the first rotor for electrically connect the battery to the windings of the first rotor. This is done in a conventional way through brushes 40 bearing against the slip rings, which may be lifted away from contact with the slip rings through members 39 (see Fig 3). Members 41 schematically indicated are arranged to establish a metallic contact between the windings of the first rotor and the power source upon such lifting away. For making the energy converter compact it may be an advantage to arrange the slip rings in said space, but it may also be advantageous to instead arrange them in the way shown in Fig 3 for having them more accessible.

In the embodiment according to Fig 3 the shaft of the second rotor, i.e. the drive shaft 10, is made hollow and arranged to receive the shaft of the first rotor, i.e. the output shaft 2 of the internal combustion engine, adapted to project through and out past the shaft of the second rotor. The slip rings 19 are here arranged on the part of the shaft of the first rotor projecting out of the shaft of the second rotor for being easily accessible, while also the shaft of the first rotor is made hollow for accommodating conductors 20 for electrically connecting the slip rings to the windings 15 of the first rotor.

By means of Fig 4 the connection between power flux and torques transferred in dependence of the numbers of revolutions of the internal combustion engine, i.e. the first rotor, and the drive shaft, i.e. the second rotor, of the hybrid drive device according to the invention will now be explained. For the power P_4 transferred to the drive shaft it is valid that it is $P_1 + P_2 + P_3$, in

which P_1, P_2 and P_3 are power supplied through the internal combustion engine, the windings of the first rotor and the windings of the stator, respectively. The following is valid for these:

$$P_1 = kT_1 \times n_1$$
$$P_2 = kT_1 \times (n_2 - n_1)$$
$$P_3 = kT_3 \times n_2$$

In which k is $2\pi/60$, while T_1 is the torque transferred through the output shaft of the internal combustion engine and T_3 is the torque transferred to the second rotor through the stator winding. n_1 and n_2 are the numbers of revolutions of the first rotor and the second rotor, respectively.

Accordingly, for the torque T_4 on the drive shaft this will be $T_1 + T_3$.

The power flow in dependence upon different relationships of the numbers of revolutions between the output shaft of the internal combustion engine n_1 and the drive shaft n_2 at different relationships between the powers P_1 and P_4 are shown in Fig 5.

The straight arrows 21 show the power flow from the internal combustion engine to the drive shaft, while the "U-arrows" 22 show the power flow between the battery and the first machine and the arrows 23 the power flow between the stator winding and the battery. It appears for example how in the case of $n_2 > n_1$ and $P_4 = P_1$ the rotor windings are fed through the arrow 22'. In the case of $n_2 = n_1$ and $P_4 > P_1$ electrical energy is supplied to the drive shaft through the stator windings according to the arrow 23', while at the same relationship of number of revolutions and $P_4 < P_1$ energy is fed in the opposite direction to the battery as indicated through the arrow 23".

A preferred embodiment of the energy converter of a hybrid drive device according to the invention is illustrated in Fig 6, in which the second electric machine is a synchronous reluctance machine by the fact that the second rotor 5 connected to the drive shaft on the outer side thereof has poles 24 being magnetically imprinted for increasing the reactance between the stator 6 and the rotor at the poles with respect to that prevailing between these poles by a shorter air gap there, so that a current in the stator windings will cause a magnetic flux resulting thereof to try to close through the iron of the rotor in the easiest possible way, i.e. where the air gap between the rotor and the stator is the smallest, and if the pole makes an angle with respect to the magnetic flux a torque is generated on the rotor, which tries to turn the pole to be aligned with respect to the magnetic flux. This constitutes conventional technique for synchronous reluctance machines. The main advantage of using a synchronous reluctance machine instead of a permanent magnet machine as second electric machine is that the iron losses are eliminated when the second electric machine is disactivated. However, in the case of a permanent magnetic machine the stator winding 16 could be designed as a winding arranged in an air gap, such as a ring winding instead of a drum winding. By removing the "teeth" 38 flow pulsations and thereby heat generation is avoided.

It is shown in Fig 7 how pieces 25 of a material, which may be air, is arranged to function as a barrier for magnetic flux for reducing the reactance for magnetic flux going between the stator and the rotor through portions in the rotor between two adjacent poles magnetically imprinted, are inserted in the rotor. The reactance for a magnetic flux through the stator, to a pole of the rotor magnetically imprinted and back to the stator through an adjacent pole of the rotor magnetically imprinted with respect to the reactance for a magnetic flux through the stator, to a portion between the poles of the rotor magnetically imprinted and then back to the stator, may hereby be increased and the

possibilities to a torque addition through the second electric machine may be improved. It is here also illustrated that the space between adjacent poles is filled with a material 26 with a low permeability for receiving an outer even surface on the rotor, and it is by this shown that poles magnetically imprinted does not have to mean poles physically imprinted.

Furthermore, Fig 8 shows another possibility to obtain a high relationship between said reactance's for a possibility to a good transfer of torques, which is based on the fact that the rotor comprises a plurality of material layers 27 superposed in the direction towards the stator, i.e. the rotor is axially laminated. Massive or laminated poles are here inserted so as to guide the flux to the inner layers. It is also possible to construct the rotor of an anisotrophe material, for example a powder, which has a high permeability in the pole direction and in the tangential direction of the rotor and a low permeability perpendicularly to these directions for obtaining a high such relationship. Thus, the permeability is then high in the directions indicated by the arrows 28 and low in the directions indicated by the arrows 29 in Fig 9.

It is shown in Fig 9 how the arrangement of permanent magnets 17 on the inner side of the second rotor is co-ordinated with the design of the magnetical imprinting on the outer side of the rotor, more exactly by arranging permanent magnets substantially straight in front of the poles magnetically imprinted, so that magnet flux through the rotor deriving on one hand from the permanent magnets and on the other from the reluctance machine run in substantially the same direction and to a substantial part cancel each other out, so that the thickness of the rotor may be made smaller, since it is only necessary to consider one machine with respect to the saturation of the iron. Accordingly, it may be said that the magnetic circuit is connected to both the stator and the two rotors.

An embodiment of the energy converter according to the invention in the form of a so called double axial machine is shown in Fig 10, i.e. the stator 6 is adapted to act through the winding 16 thereof on surfaces directed substantially axially, i.e. permanent magnets 18 of the second rotor 5, from an axially opposite direction to the influence of the first rotor 4 upon the second rotor through magnetic flux directed substantially axially and emanating from the rotor windings 15. The advantages of such a machine have been disclosed further above.

A further variant of the energy converter in the form of a so called radial axial machine is shown in Fig 11, which differs from the energy converter shown in Fig 2 by the fact that the stator 6 is arranged in the direction of the axis of rotation of the rotors substantially after the second rotor 5 so as to co-operate with surfaces of the second rotor directed substantially axially in the direction of the axis of rotation of the second rotor, in which these surfaces are provided with permanent magnets 18, through a substantially axially magnetic flux between the stator and this rotor. The advantages of such an embodiment have also been discussed further above.

A hybrid drive device according to an embodiment is shown in Fig 12, which, as the embodiment according to Fig 11, has an energy converter comprising a so called radial-axial-machine, but in this the second rotor has two rotor discs 42, 43, which are arranged at an axial distance. The stator 6 is arranged between these rotor discs, and this is formed by a toroid core 44 in the form of sheet band wound as a tape role and a winding 45 laid therearound, for example a three phase winding. This machine may be said to be of toroid type. The stator has an axial air gap 46, 47 to the respective rotor disc for transmitting power through magnetism there through flux directed substantially axially. By arranging two such air gaps a balancing of axial forces on the rotor takes place and costly axial bearings are therefore not necessary. The combination of radial and axial

machine is interesting, since a requirement of operation without hitting the ground leads to a requirement of a minimum diameter, while there is space in the axial direction. It is then advantageous to make the diameter of the first electric machine as large as possible for obtaining a highest possible torque.

The embodiment of the hybrid drive device shown in Fig 13 differs from the one according to Fig 12 mainly by the use of a planetary gearing 11 instead of reducing the number of revolutions of the shaft 10 of the second rotor to the wheel axle. A planetary gear may be interesting in installations having an engine extending in the longitudinal direction (for example smaller lorries), while passenger cars normally have an engine extending transversely, and there is then a need for "laterally displace" drive shafts out to the wheels, so that the gear alternative according to Fig 12 is preferred.

A hybrid drive device according to an embodiment of the invention is illustrated in Fig 14 and which has large similarities to the embodiments shown in Figs 12 and 13 as far as the energy converter comprises a so called radial-axial-machine and the second rotor has in this two rotor discs 49, 50, which are arranged on an axial distance and rigidly connected with respect to each other through the output shaft 10. This rotor co-operates also with the first rotor 4 through permanent magnets 15, but the first rotor 4 is here unlike the embodiments according to Figs 12 and 13 provided with a magnetizing winding 51 instead of permanent magnets.

Also in this embodiment a stator 6 is arranged between the two rotor discs of the second rotor and this is formed by a toroid core 44 in the form of sheet band wound like a tape role and a winding 45 laid therearound, for example a three phase winding, in a way to be explained further below with reference to Fig 16. Thus, this machine may be said to be of toroid type. The stator has an axial air gap 46, 47 to the respective rotor disc for

transmitting power through magnetism there through flux directed substantially axially. By arranging two such air gaps a balancing of axial forces upon the rotor takes place and no costly axial bearings are therefore required.

A considerable difference between this embodiment and the one according to Figs 12 and 13 is that the second electric machine is an axial synchronous reluctance machine by the fact that the rotor discs do not have any permanent magnets but instead have poles magnetically imprinted in a similar way to the one illustrated in and described with reference to Figs 6-9. How this is achieved in the practice is illustrated in Fig 15. A part of the sheet wound in a plurality of layers superposed to each other for forming the respective rotor disc is shown there. Openings 53 in the form of slots with a substantially V-shape are punched out in the sheet band 52. The tip of the V's points substantially in axial direction. Poles 54 are in this way imprinted between each set 55 of a plurality of such openings with V-shape received in each other as illustrated in Fig 15. The air openings 53 of a substantially V-shape will namely form pieces with a lower reactance than the sheet border portion between subsequent sets 55, so that there at 54 a pole magnetically imprinted having a higher reactance is formed. The magnet flux formed through a current in the windings of the stator 6 will accordingly mean that the magnetic flux resulting thereof will try to be closed through the rotor in the easiest possible way, i.e. where the reactance is the highest.

It is illustrated in Fig 16 how the stator is formed in the embodiment according to Fig 14, more exactly with slots 56 running substantially transversely to the longitudinal extension of the toroid core 44 around the toroid core and adapted to receive the winding 45 arranged around the toroid core substantially entirely within the slots. For ensuring this cover members 57, so called slot wedges, in the form of small lids are arranged to cover the winding of each slot and preventing magnetic

forces from drawing any part of the winding out of any slot. An advantage of this embodiment of the invention is that the pattern punched out in the sheet strip forming the rotor results in a very high relationship between the reactance of the pole 54 and the reactance between the poles. An advantage of this embodiment with respect to the one according to Fig 12 is that the second electric machine, i.e. the axial synchronous reluctance machine, will get a high temperature resistance, i.e. will withstand high temperatures very well, thanks to the lack of permanent magnets. Furthermore, it will be less costly since no permanent magnets are needed. Of course the other slots have also a winding received therein, although such a winding is only shown in one slot for the sake of simplicity.

A hybrid drive device being modified with respect to the embodiments discussed above is illustrated in Fig 17, and this has no second electric machine, but is instead provided with a gear 30 with a variable gear change, for example a gear with a continuous variable gear change, a so called CVT (continuous variable transmission), which is connected to the shaft of the second rotor of the electric machine. An arrangement 31 for controlling the energy exchange between the battery 7 and the rotor windings of the first rotor is arranged to co-operate with the gear 30, so that it will be possible to change the torque of the drive shaft 10 without for that sake change the number of revolutions or the torque of the output shaft of the internal combustion engine in a way described above.

By arranging the gear 30 and the second electric machine, respectively, of the hybrid drive device according to the invention it will be possible to let the internal combustion engine in determined situations operate at a number of revolutions and a torque being an optimum with respect to the efficiency and the emission of exhaust gases independently of the torque required by the drive shaft 10. This optimum number of revolutions and torque is determined by the characteristic of the internal com-

bustion engine, which may be obtained through engine tests at different loads on the engine.

The hybrid drive device also comprises a locking arrangement 32 schematically indicated in Fig 3 for interlocking parts of the device movable with respect to each other or such parts and a stationary frame with respect to rotation, and this locking arrangement comprises members schematically indicated for enabling interlocking of the output shaft from the internal combustion engine and the drive shaft. A wheeled vehicle may then for example be driven only through the internal combustion engine. A control arrangement 34 is then arranged to make the position of the locking member 33 dependent upon whether an energy exchange between the windings of the first rotor and the power source interacting therewith takes place or not and automatically interrupt the interlocking when establishing an electric current between the power source and the rotor windings and activate the interlocking when such a current disappears. This may be obtained by arranging members 35 to detect a current in the rotor windings and control the locking members depending upon this detection. Furthermore, the locking arrangement comprises members 36 schematically indicated and adapted to enable a locking of the output shaft of the internal combustion engine with respect to the stationary frame 37, such as a vehicle chassis, with respect to rotation and the control arrangement 34 is adapted to control the locking members 36 to establish such a locking as long as the internal combustion engine is turned off. It is hereby avoided that when the internal combustion engine is turned off, i.e. when driving under electrical operation, the reaction torque from the driving pushes the internal combustion engine back. It would be completely possible to coordinate the function of the two members 33 and 36 by one single member able to assume three positions, namely a first resulting in a total release of movable parts, a second resulting in a securing of the output shaft of the internal combustion engine with respect to the frame, and a third resulting in a rigid

connection with respect to rotation of the two rotors with respect to each other.

It is understood that many different operation modes of the hybrid drive device according to the invention being advantageous at different load situations are offered, some of which may be mentioned here.

When driving with a so called "cruise control", i.e. with a constant speed when driving on a highway, the regulating arrangement may ensure that said locking members connect the output shaft of the internal combustion engine with the drive shaft and the wheel axle is on an even ground driven substantially only by the internal combustion engine, and electrical energy is supplied to the stator when suddenly driving uphill for giving a torque addition to the drive shaft and enable a constant speed there without changing the number of revolutions or the torque of the internal combustion engine.

The regulating arrangement may also be arranged to control supply of electric energy to the rotor windings of the first machine for driving the rotor connected to the output shaft of the internal combustion engine around for starting the internal combustion engine. It may also, at disconnection of the drive shaft from outer load (idle) and running the internal combustion engine, be adapted to guide electric energy generated in the rotor windings of the first machine through a relative movement of the first and second rotor generated through rotation of the output shaft of the internal combustion engine to the battery for charging thereof.

The regulating arrangement is also, at a low outer load on the drive shaft, adapted to guide a part of the energy supplied to the energy converter through the output shaft of the internal combustion engine as electrical energy from the rotor windings and the stator windings to the battery for charging thereof. At a

high outer load on the drive shaft the regulating arrangement guides electrical energy from the battery to the rotor windings as well as to the stator windings for energy supply to the drive shaft.

The regulating arrangement is also adapted to control a member 48 schematically indicated in Fig 1 to interrupt the supply of fuel to the internal combustion engine and the electric machine/the electric machines to feed kinetic energy of the drive shaft to the power source when braking the drive shaft. For maintaining the number of revolutions it is then possible to feed power to the shaft of the internal combustion engine, i.e. the same power direction as when starting the internal combustion engine. It may then be chosen to exactly maintain the number of revolutions or to feed extra power in and then obtain a mechanical engine braking exactly as for a normal car. The primary advantage of this is that fuel is saved during all brakings. A maximum space for storing brake energy is at the same time created in the power source, such as a battery, since the internal combustion engine does not "steel any space" by feeding power out. Another advantage is that it is possible to obtain an improved generative power ability without using extra electric resistors for dumping energy therein, since the cooling system of the engine is used as power dump, and there is normally a good over-capacity therein. Furthermore, it is easier to obtain an unambiguous behaviour in regenerative braking, since the braking ability will not be associated with the degree of charging of the battery, which is normally a problem.

The regulating arrangement is also, when the internal combustion engine is running and load is applied on said drive shaft, arranged to be able to obtain regenerative braking thereof through energy supply from said windings to the battery. By supplying electrical energy to the windings of the rotor in such a way that the second rotor at a given direction of rotation of the output shaft of the internal combustion engine is influenced

thereby to rotate in the opposite direction than normally the regulating arrangement may obtain a reverse of the direction of rotation of the drive shaft, so that in this way reversing of a wheeled vehicle may take place without using any real reverse gear.

The invention is of course not in any way restricted to the preferred embodiments described above, but many possibilities to modifications thereof will be apparent to a man skilled in the art without departing from the basic idea of the invention as defined in the appended claims.

It would for example be possible to use an asynchronous motor as said second electric machine. The power sources for the two electric machines could be completely different than those discussed above, and it would also be possible to have a separate power source for each electric machine. The power source may then be an energy-storing member in the form of a flywheel. Neither is it necessary to have a converter, but it would be completely possible to interconnect alternating voltage systems having different frequencies. Thus, it is well possible to use an alternating voltage source as energy buffer or energy or power source, in which this could even be a "wall socket" connected to the general electric network or any industrial network.

It would for example be possible to provide the second rotor with windings and not have any windings on the stator, and instead provide the latter with permanent magnets, a magnetic winding or designing it as a reluctance machine, but in such a case it will be necessary to have slip rings for both rotors.

It is pointed out that regeneration may take place at pure electrical operation and in hybrid operation.

The reluctance machine does not have to be a synchronous reluctance machine, but it could very well be a so called switched

reluctance machine, which is fed with a square-wave like current and has imprinted pools also in the stator, in which the numbers of pools in the stator and the rotor are normally different.

It is pointed out that a direct voltage may very well be present in the rotor winding instead of an alternating voltage, but in such a case it has to exist an alternating voltage in the winding of the second rotor, and the definition in claim 1 "to exchange electrical energy with said windings through alternating voltage in said windings" is intended to comprise also that case.

Claims

1. A hybrid drive device comprising an internal combustion engine (1), an energy converter (3) adapted to co-operate with an output shaft (2) of the internal combustion engine and which comprises at least one electric machine having a first (4) and a second (5) rotor, which are adapted to co-operate with each other by transmitting power through magnetism and may rotate with different number of revolutions, at least one of which being provided with one or a plurality of windings (15), and a power source (7) adapted to exchange electrical energy with said windings through an alternating voltage in said windings for a co-operation of the rotors by transmitting power through magnetism, ***characterized*** in that the energy converter comprises a unit (5, 6, 30) adapted to be able to influence the torque of a drive shaft (10) out from the energy converter without changing the number of revolutions of this shaft or changing the number of revolutions of the output shaft of the internal combustion engine, and that the device comprises a regulating arrangement (14) adapted to co-ordinate control of energy flows to and from the internal combustion engine, the electric machine and said unit.

2. A device according to claim 1, ***characterized*** in that said unit comprises a second electric machine having at least a rotor (5) connected to said drive shaft (10) and a stator (6), that at least one of the stator and the rotor of the second electric machine is provided with windings and that the power source (7) is adapted to exchange electrical energy with the windings (16) last mentioned through an alternating voltage in said windings for co-operation of the rotor and the stator of the second machine by transmitting power through magnetism and thereby of the stator and said drive shaft out from the energy converter.

3. A device according to claim 2, ***characterized*** in that the stator (6) is provided with said windings (16) arranged for exchanging electrical energy with the power source (7).

4. A device according to any of claims 1-3, ***characterized*** in that it comprises an arrangement (32) for interlocking pieces of the device movable with respect to each other or such pieces and a stationary frame (37) with respect to rotation, and that it also comprises a control arrangement (34) adapted to control the locking arrangement to assume a position interlocking said pieces or releasing said pieces with respect to each other depending upon the operation condition of the device.

5. A device according to claim 4, ***characterized*** in that the locking arrangement comprises members (33) adapted to enable interlocking of the output shaft (2) from the internal combustion engine and said drive shaft (10).

6. A device according to claim 5, ***characterized*** in that said locking members (33) are adapted to be able to interlock said first (4) and second (5) rotor of the energy converter with respect to rotation so as to interlock the output shaft of the internal combustion engine and the drive shaft in that way.

7. A device according to claim 6, ***characterized*** in that the control arrangement (34) is adapted to make the position of said locking members dependent upon whether energy exchange between said rotor windings and the power source interacting therewith takes place and automatically interrupt the interlocking upon establishing of an electric current between the power source and the rotor windings and activate the interlocking when such a current disappears.

8. A device according to claim 7, ***characterized*** in that the control arrangement comprises members (35) adapted to detect

a current in the windings of the rotor and control the locking members in dependence upon this detection.

9. A device according to claim 2 or 3 and any of claims 4-8, ***characterized*** in that the control arrangement is adapted to control the locking arrangement (34) to realize said interlocking in an operation case of the device in which there is a desire to drive the drive shaft only through the internal combustion engine with assistance of the second electric machine when there is a need for an additional torque on the drive shaft.

10. A device according to any of claims 4-8, ***characterized*** in that the locking arrangement comprises members (36) adapted to enable a locking of the output shaft (2) of the internal combustion engine with respect to rotation with respect to a stationary frame (37), and that the control arrangement is adapted to control the locking members last mentioned to establish such a locking as long as the internal combustion engine is turned off.

11. A device according to any of claims 1-10, ***characterized*** in that the first (4) and the second (5) rotor are substantially concentrically arranged with the first one received in a space enclosed by the second one for generating substantially radially magnetic flux therebetween.

12. A device according to claim 11, ***characterized*** in that the first rotor (4) is provided with windings (15), that slip rings (19) are arranged on a shaft (2) of the first rotor inside a space delimited by the first rotor for electrically connecting said power source (7) to the windings of the first rotor.

13. A device according to claim 11, ***characterized*** in that the first rotor (4) is provided with windings, that the shaft (10) of the second rotor (5) is hollow and adapted to receive the shaft (2) of the first rotor adapted to project through and out past

the shaft of the second rotor, that slip rings (19) for transmitting electricity between said power source (7) and the windings of the first rotor are arranged on the part of the shaft of the first rotor projecting out of the shaft of the second rotor opposite to said space, and that the shaft of the first rotor is hollow for housing conductors (20) for electrically connecting the slip rings to the windings of the first rotor.

14. A device according to any of claims 1-10, ***characterized*** in that the first (4) and the second (5) rotor are arranged with their axes of rotation substantially coinciding with each other and with surfaces for co-operating by transmitting power through magnetism directed substantially in the direction of said axes of rotation for substantially axial magnetic flux between the two rotors.

15. A device according to claim 14, ***characterized*** in that at least one of the rotors has a plurality of rotor discs (42, 43) with surfaces for co-operating with surfaces of the other rotor directed substantially in the direction of said axes of rotation by transmitting power through magnetism, so that several couples of surfaces co-operates by transmitting power with an axial air gap (46, 47) therebetween.

16. A device according to claim 15, ***characterized*** in that the number of said axial air gaps is 2n, in which n is an integer ≥ 1.

17. A device according to claim 2 and possibly any of claims 4-16, ***characterized*** in that one of the rotors of the first electric machine also forms the rotor (5) of the second electric machine.

18. A device according to claim 17 and any of claims 11-13, ***characterized*** in that the second rotor (5) of the first electric machine forms the rotor for the second electric machine, and that the stator (6) is arranged radially outside the second

rotor for acting thereupon through substantially radial magnetic flux.

19. A device according to claim 3 and any of claims 11-13, ***characterized*** in that the second rotor (5) of the first electric machine forms the rotor for the second electric machine, and that the stator (6) is arranged to co-operate with surfaces of the second rotor directed substantially axially with respect to the axis of rotation of the second rotor through a substantially axial magnetic flux between the stator and this rotor.

20. A device according to claim 19, ***characterized*** in that the stator (6) and the second rotor (5) are adapted to co-operate by transmitting power through magnetism through substantially axial air gaps (46, 47) between surfaces thereof, and that the number of such axial air gaps is 2n, in which n is an integer ≥ 1.

21. A device according to claim 20, ***characterized*** in that the second rotor (5) has a plurality of rotor discs (42, 43) separated axially and the stator has a plurality of stator pieces separated axially, and that the stator pieces and the rotor discs are arranged alternatingly in the axial direction for transmitting power through magnetism therebetween.

22. A device according to claim 20 or 21, ***characterized*** in that the stator (6) comprises a toroid core (44) with a centre axis substantially coinciding with the axis of rotation of the second rotor (5), and that a winding (45) is arranged around the core and adapted to co-operate by transmitting power through magnetism with rotor discs of the second rotor arranged axially on both sides thereof.

23. A device according to claim 22, ***characterized*** in that the toroid core (44) of the stator is provided with slots (56) running around the toroid core substantially transversely to the longitudinal direction thereof and adapted to receive the wind-

ing arranged around the toroid core substantially entirely within the slots.

24. A device according to claim 23, ***characterized*** in that the stator (6) is provided with members (57) adapted to cover the winding (45) of each slot and prevent magnetic forces from drawing any part of the winding out of any slot.

25. A device according to any of the preceding claims, ***characterized*** in that the second rotor (5) is provided with permanent magnets for said transmittance of power through magnetism.

26. A device according to claims 2 and 14, ***characterized*** in that the stator (6) is adapted to act upon surfaces of the second rotor (5) directed substantially axially from the opposite direction as seen in the axial direction to the influence of the first rotor (4) on the second rotor through magnetic flux directed substantially axially.

27. A device according to claim 2 and possibly any of claims 3-26, ***characterized*** in that the second electric machine is a reluctance machine with poles (24) magnetically imprinted on the rotor (5) thereof for increasing the reactance between the stator (6) and the rotor at the poles with respect to between these poles.

28. A device according to claim 27, ***characterized*** in that it comprises means (25, 27) for increasing the relationship between the reactance for a magnetic flux through the stator (6), to a pole (24) of the rotor (5) being magnetically imprinted and back to the stator through an adjacent pole of the rotor being magnetically imprinted with respect to the reactance for a magnetic flux through the stator, to a portion between poles of the rotor being magnetically imprinted and then back to the stator.

29. A device according to claim 28, ***characterized*** in that said means are formed by pieces (25) of a material arranged to function as a barrier for magnetic flux laid in the rotor substantially at the location of the portions between two adjacent poles (24) being magnetically imprinted so as to reduce the reactance for magnetic flux between the stator and the rotor through said portions.

30. A device according to claim 29, ***characterized*** in that said barrier material is air.

31. A device according to claim 30, ***characterized*** in that the rotor (5) is annular and the pieces are formed by openings (53) running substantially radially through the rotor.

32. A device according to claim 31, ***characterized*** in that the openings have substantially a V-shape as seen in the radial direction with the tip of the V pointing substantially axially.

33. A device according to claim 32, ***characterized*** in that each said piece between each pole is formed by a plurality of openings (55) with said V-shapes of different sizes following upon each other in the axial direction and with the V's received in each other.

34. A device according to any of claims 28-33, ***characterized*** in that the rotor (5) comprises a plurality of material layers (52) arranged in turns superposed on each other while forming a ring having a diameter growing for each layer.

35. A device according to claim 28, ***characterized*** in that said means are realized by the fact that the rotor (5) comprises a plurality of material layers (27) superposed onto each other in the direction towards the stator.

36. A device according to claim 17 and any of claims 27-35, ***characterized*** in that the second rotor (5) has permanent magnets (17) on the opposite side thereof with respect to the poles (24) being magnetically imprinted for co-operating with the windings of the first rotor.

37. A device according to claims 11 and 36, ***characterized*** in that the permanent magnets (17) are arranged on the radially inner side of the second rotor (5).

38. A device according to claim 36 or 37, ***characterized*** in that the magnetic imprint on one side of the rotor and the arrangement on the permanent magnets (17) on the opposite side thereof are adapted to each other in such a way that the magnetic flux through the rotor deriving on one hand from the permanent magnets and on the other from the reluctance machine run in substantially opposite directions and mainly cancel each other out.

39. A device according to claim 38, ***characterized*** in that the permanent magnets (17) are arranged substantially straight in front of the poles (24) magnetically imprinted.

40. A device according to any of claims 27-39, ***characterized*** in that the second electric machine is a synchronous reluctance machine.

41. A device according to claim 12 or 13, ***characterized*** in that the first rotor (4) is arranged on an input shaft (2) on the internal combustion engine side of the energy converter, and that it comprises members (41) adapted to establish an electric connection between the windings of the first rotor (4) and the power source (7) parallel to a connection thereof through brushes (40) bearing against the slip rings (19) when the output shaft (2) of the internal combustion engine is not moving.

42. A device according to claim 41, ***characterized*** in that it comprises members (39) adapted to lift the brushes (40) from the contact with the slip rings (19) when the output shaft (2) of the internal combustion engine is not moving.

43. A device according to any of claims 1-42, ***characterized*** in that said power source (7) is a direct current source, such as an electric battery, and that this is connected to said windings through a converter (8, 9).

44. A device according to any of claims 1-43, ***characterized*** in that it comprises a gear (11) adapted to reduce the number of revolutions between the output shaft of the internal combustion engine and said drive shaft, and that this gear is arranged either between the internal combustion engine (1) and the energy converter (3) or on the same side of the energy converter as the drive shaft (10).

45. A device according to any of claims 4-8, 10-14, 43 and 44, ***characterized*** in that said unit is a gear (30) having a variable gear change connected to one of the rotors (5) of the energy converter, and that this gear and an arrangement (31) for controlling the energy exchange between the power source and the rotor provided with windings are adapted to co-operate.

46. A device according to any of the preceding claims, ***characterized*** in that the regulating arrangement (14) is adapted to control the power supply from the power source to the windings and interrupt the power supply to the internal combustion engine and keep the output shaft thereof at rest so as to achieve only electric driving of the drive shaft (10).

47. A device according to claim 2, ***characterized*** in that the regulating arrangement (14) is adapted to interrupt the power supply to the internal combustion engine and keep the output shaft thereof at rest, lead electric energy generated in the sta-

tor winding through forces of inertia of a piece being in a power transmitting relation to the drive shaft and which rotates the rotor of the second machine to the power source for electric braking of the movement of the drive shaft.

48. A device according to any of the preceding claims, ***characterized*** in that the regulation arrangement (14) is adapted to control a member (48) when the drive shaft (10) is slowed down to interrupt the supply of fuel to the internal combustion engine (1) and the electric machine/the electric machines and feed kinetic energy of the drive shaft to said power source (7).

49. A device according to claim 48, ***characterized*** in that the regulating arrangement (14) is, when the drive shaft is slowed down, adapted to control transfer of a part of the kinetic energy of the drive shaft as well to the shaft (2) of the internal combustion engine for motor braking.

50. A device according to any of the preceding claims, ***characterized*** in that the regulating arrangement (14) is adapted to control the supply of electrical energy to the rotor windings (15) of the first machine for rotating the rotor (4) connected to the output shaft (2) of the internal combustion engine for starting the internal combustion engine.

51. A device according to claims 2 and 50, ***characterized*** in that the regulating arrangement (14) is adapted to control the second electric machine to create a torque resistance and the first electric machine to produce a desired number of revolutions of the output shaft (2) of the internal combustion engine when starting the internal combustion engine.

52. A device according to any of the preceding claims, ***characterized*** in that the regulating arrangement (14) is, when the drive shaft (10) is disconnected from outer load (idle) and the internal combustion engine is running, adapted to guide electri-

cal energy generated in the rotor windings of the first machine through a relative movement of the first (4) with respect to the second (5) rotor generated by the rotation of the output shaft of the internal combustion engine to said power source for charging thereof.

53. A device according to claim 2, ***characterized*** in that the regulating arrangement (14) is, at a low outer load on the drive shaft, adapted to guide a part of the energy supplied to the energy converter through the output shaft (2) of the internal combustion engine as electrical energy from the rotor windings (15) and the stator windings (16) to said power source (17) for charging thereof.

54. A device according to claim 2, ***characterized*** in that the regulating arrangement (14) is, at a high outer load on the drive shaft (10), adapted to guide electrical energy from said power source (7) to the rotor windings (15) as well as to the stator windings (16) for energy supply to the drive shaft.

55. A device according to claim 9, ***characterized*** in that the regulating arrangement (14) is, when there is a desire of fixing the rotation speed of the drive shaft at a determined level, adapted to control the energy supply to the internal combustion engine so that this is constant and the output shaft (2) of the internal combustion engine has a determined number of revolutions and when the load on the drive shaft (10) increases to control supply of electrical energy from the power source to the windings (16) of the stator for maintaining the same relation of numbers of revolutions of the second rotor with respect to the first one driven by the internal combustion engine.

56. A device according to any of the preceding claims, ***characterized*** in that the regulating arrangement (14) is, when the internal combustion engine (1) is running and a load is supplied on said drive shaft (10), adapted to cause a regenerating brak-

ing thereof through energy supply from said windings (15, 16) to the power source (7).

57. A device according to any of the preceding claims, ***characterized*** in that the regulating arrangement (14) is adapted to supply electrical energy to said windings (15) in such a way that the second rotor (5) at a given direction of rotation of the output shaft (2) of the internal combustion engine is influenced thereby to rotate in another direction than normally for obtaining a reversal of the direction of rotation of the drive shaft.

58. A device according to claim 45, ***characterized*** in that the regulating arrangement (14) is, when there is a need of changing the torque of the drive shaft (10), adapted to control the gear (30) to change the gear change and at the same time control the energy exchange between the electric machine and the power source (7) so that the influence of said change of the gear change of the gear upon the number of revolutions of the drive shaft is compensated by a change of the number of revolutions of that rotor (5) of the electric machine which is connected to said gear.

59. A device according to any of claims 1-58, ***characterized*** in that said drive shaft (10) is a drive shaft for driving a wheel axle (12) of a wheeled vehicle (13).

60. A vehicle, such as wheeled vehicles, railway vehicles and ships, equipped with a hybrid drive device according to any of the preceding claims.

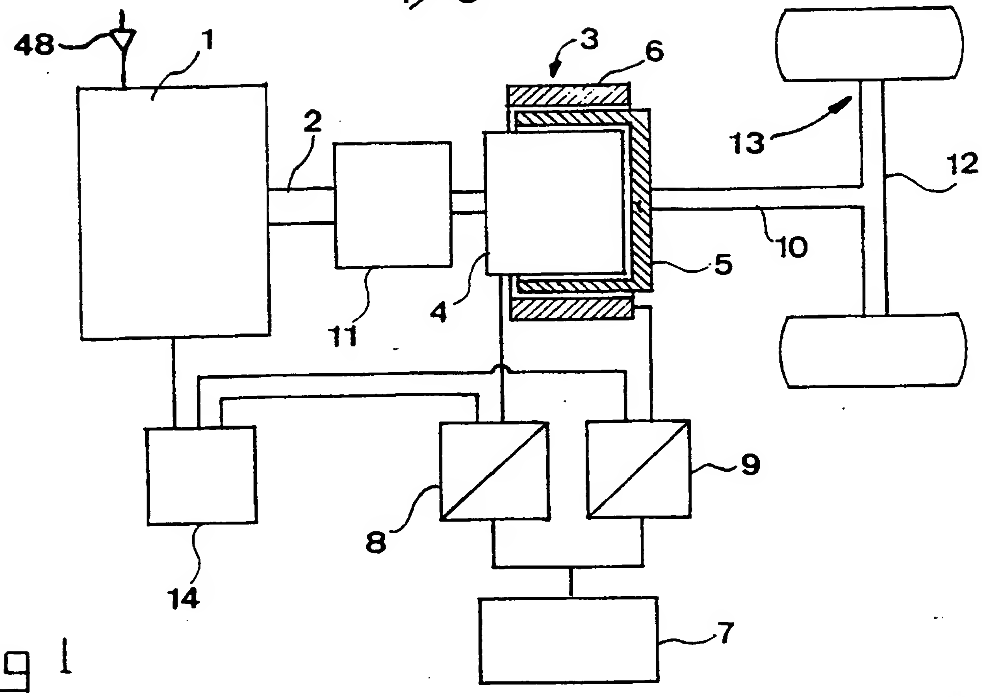


Fig 1

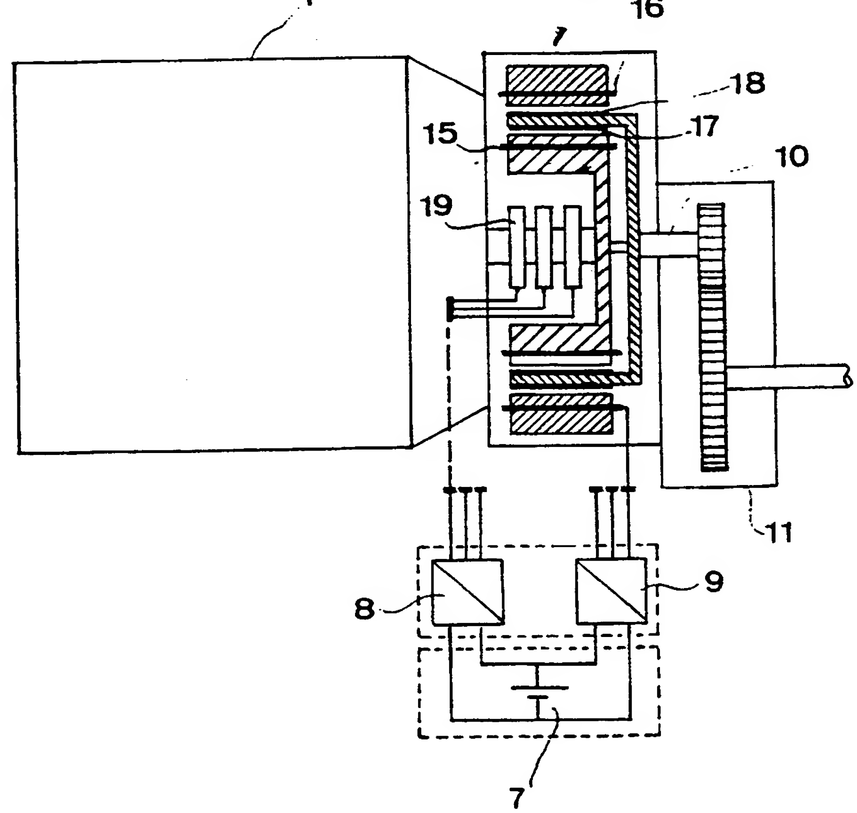


Fig 2

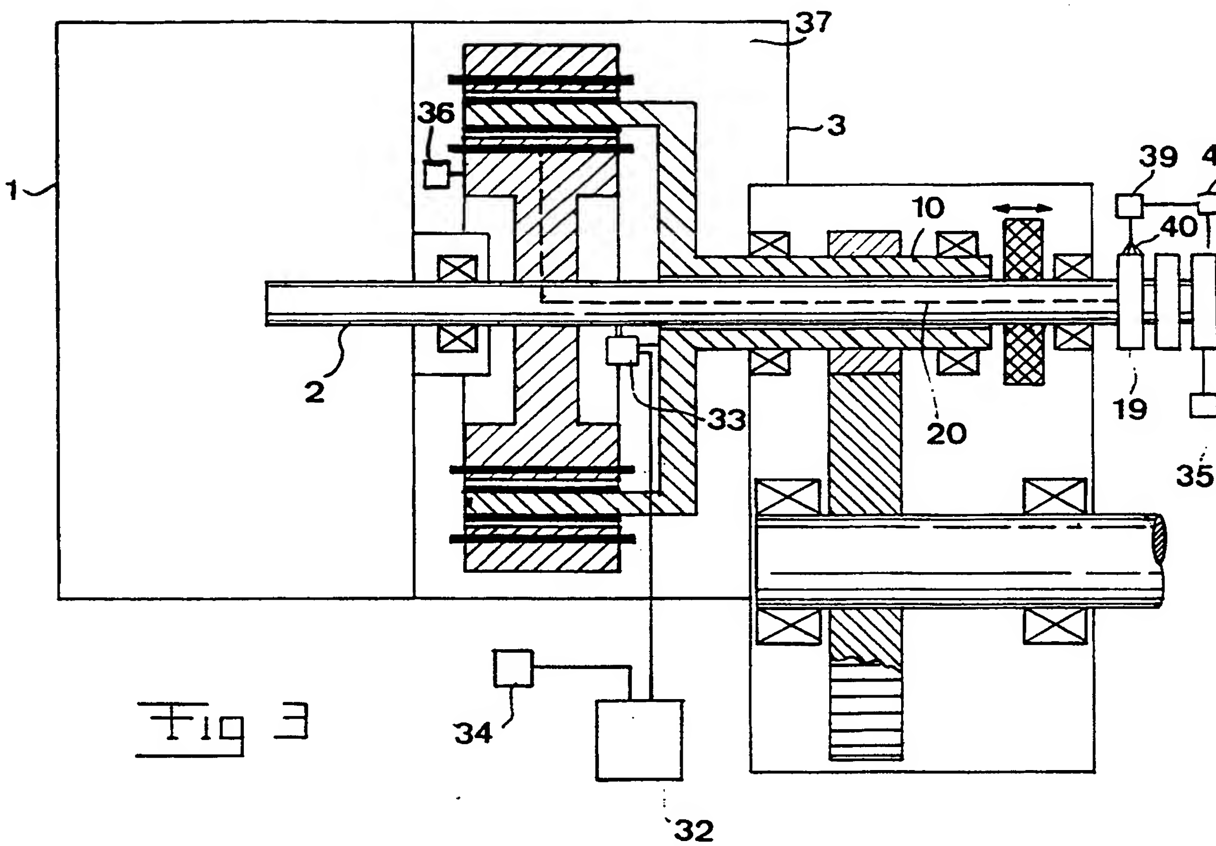


Fig 3

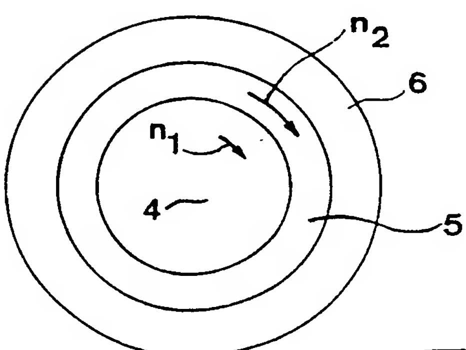


Fig 4

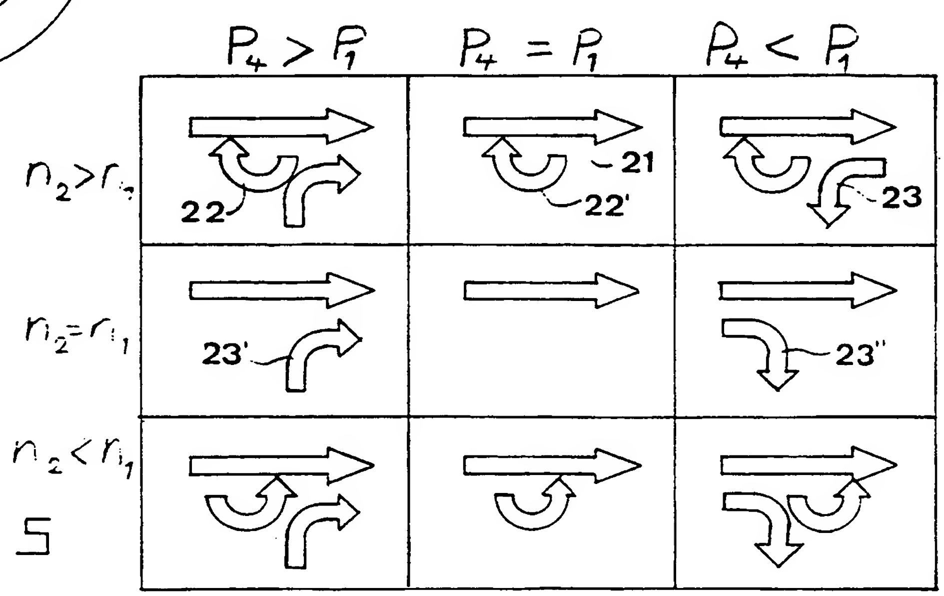


Fig 5

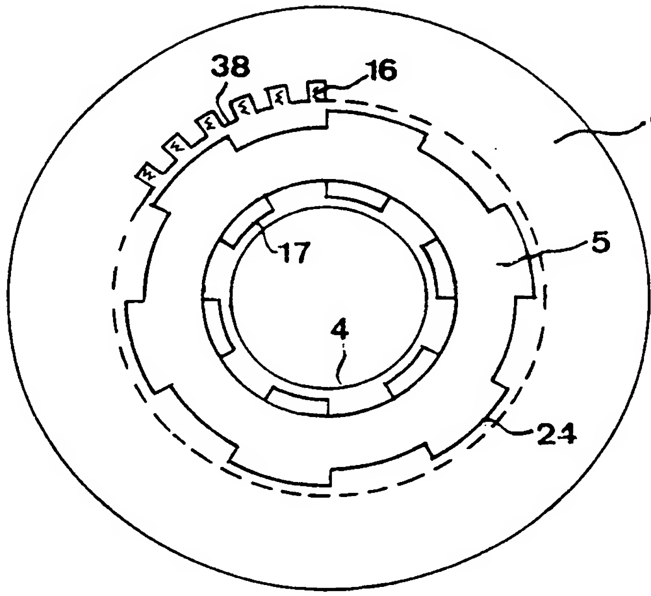


Fig 6

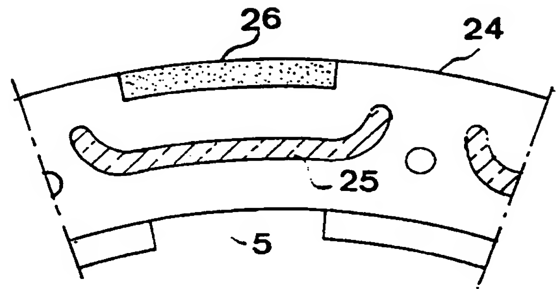


Fig 7

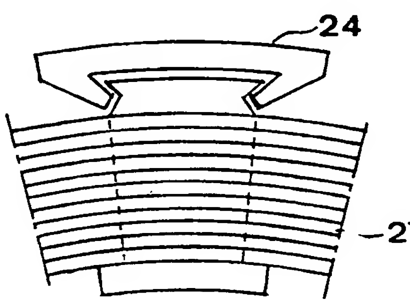


Fig 8

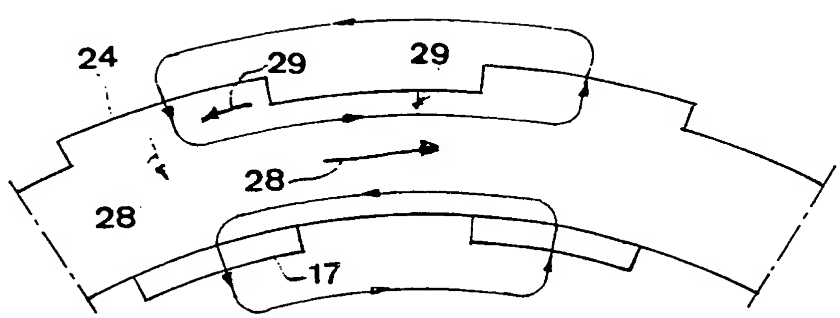


Fig 9

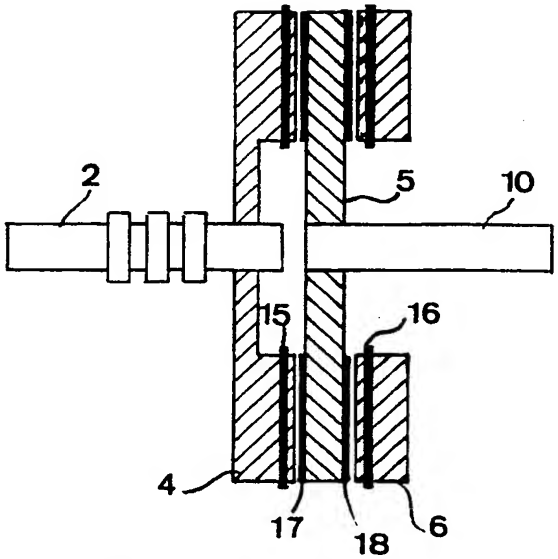


Fig 10

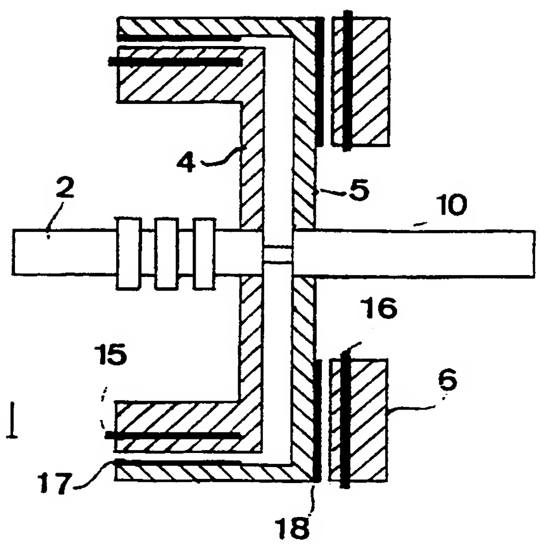


Fig 11

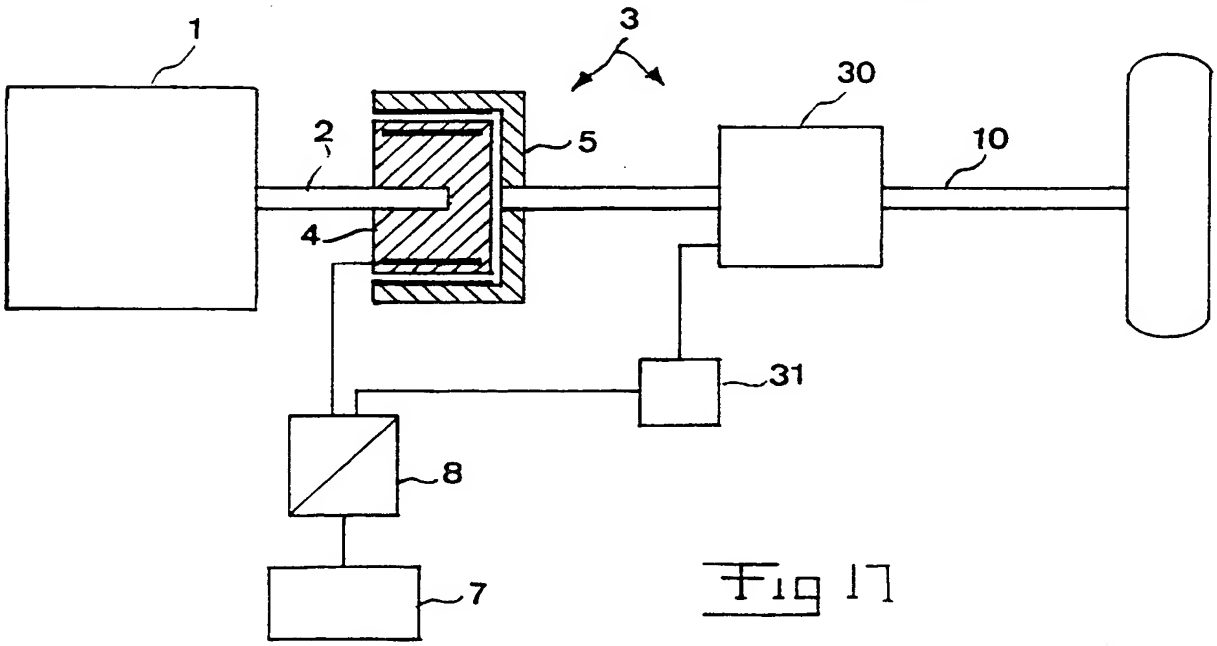


Fig 17

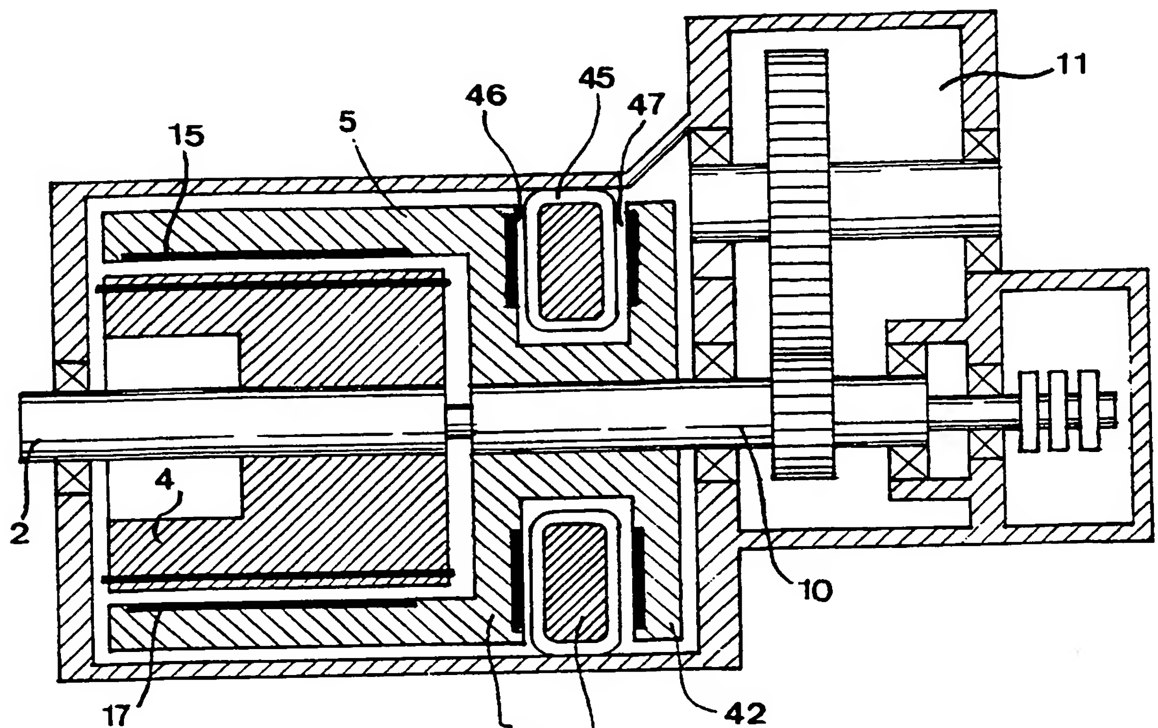


Fig 12

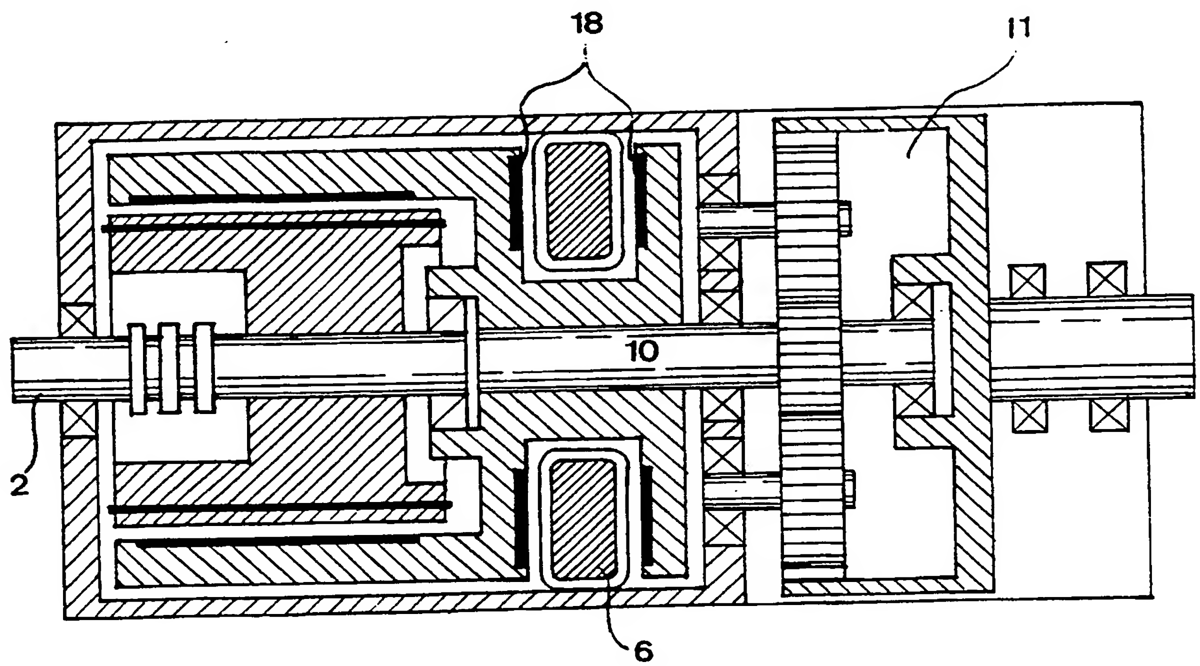


Fig 13

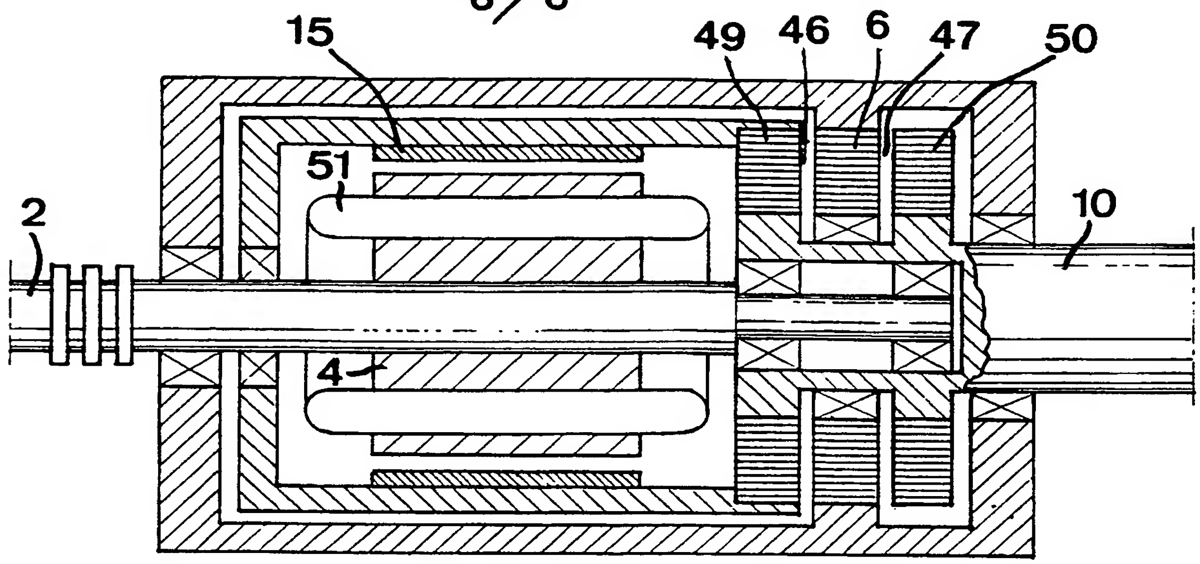


Fig 14

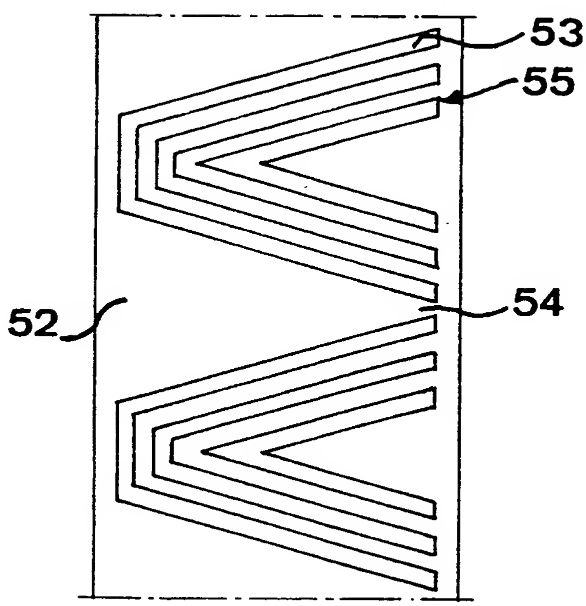


Fig 15

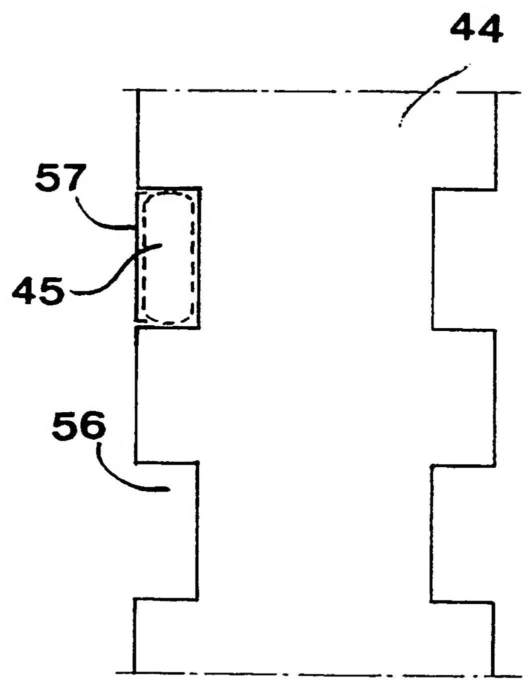


Fig 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/02276

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B60K 6/04, B60L 11/12 // H02K 16/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B60K, B60L, H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI PAJ EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0856427 A1 (DENSO CORPORATION), 5 August 1998 (05.08.98), page 3, line 35 -line 38; page 5, line 48 - page 7, line 15; page 8, line 37 - line 48, page 15, line 24 - 25. page 45, line 24 - 26	1-3,11-60
Y	figures 1-2, abstract	4-6,9
	--	
X	EP 0725474 A1 (NIPPONDENSO CO., LTD.), 7 August 1996 (07.08.96), column 4, line 9 - column 5, line 36; column 5, line 56 - column 9, line 2, figure 1, abstract	1-3,11-60
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 March 2000	14 -03- 2000
Name and mailing address of the ISA Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Joakim Movander/LR Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2630868 A1 (JEAN-PAUL SIBEUD), 3 November 1989 (03.11.89), page 6, line 26 - page 9, line 14, figure 1, abstract --	1-3,11-45, 59-60
X	EP 0800951 A1 (TOYOTA JIDOSHA KABUSHIKI KAISHA), 15 October 1997 (15.10.97), figure 1, abstract --	1,43-45, 59-60
A	WO 9709191 A1 (SADARANGANI, CHANDUR ET AL), 13 March 1997 (13.03.97), figure 4, abstract --	1,44-45
Y	EP 0743208 A2 (TOYOTA JIDOSHA KABUSHIKI KAISHA), 20 November 1996 (20.11.96), column 2, line 6 - line 58; column 28, line 30 - column 29, line 13, figures 15,19, abstract --	4-6,9
A	EP 0769403 A2 (TOYOTA JIDOSHA KABUSHIKI KAISHA), 23 April 1997 (23.04.97), figure 2, abstract --	1,44-45
A	DE 4324010 A1 (MERCEDES-BENZ), 19 January 1995 (19.01.95), figure 1, abstract --	1,43-60
A,E	EP 0917978 A2 (LOCKHEED MARTIN CORPORATION), 26 May 1999 (26.05.99), abstract --	1,46-60
A	EP 0754588 A1 (TOYOTA JIDOSHA KABUSHIKI), 22 January 1997 (22.01.97), abstract -- ---------	1,46-60

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE99/02276

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Without support from the independent claim 1, the remaining claims state four independent inventions:

I.	Claim 2-3, 11-43:	Energy converter.
II.	Claim 4-10:	Locking unit.
III.	Claim 44-45:	Gear.
IV.	Claim 46-58:	Control unit.

The special technical feature of invention I is an energy converter comprising two concentric arranged electric rotors. The two rotors actuate the torque of a driving shaft without change of the driving shafts rpm or the rpm of a combustion engine.

The special technical feature of invention II is a locking unit arranged to lock the first rotor to the second rotor, so that the combustion engines shaft will be locked to the driving shaft.

The special technical feature of invention III is a gear connected to one of the rotors for controlling the power supply between an energy source and the rotor provided with windings.

The special technical feature of invention IV is a control unit arranged to control the flux of energy in the hybrid drive system.

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 99/02276

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0856427 A1	05/08/98	JP 10098803 A	14/04/98
		WO 9804431 A	05/02/98
		JP 10084602 A	31/03/98
		JP 10094109 A	10/04/98
		JP 10155265 A	09/06/98
		JP 10238380 A	08/09/98
		JP 10238381 A	08/09/98
		JP 10243503 A	11/09/98
EP 0725474 A1	07/08/96	JP 9056010 A	25/02/97
		US 5744895 A	28/04/98
		US 5917248 A	29/06/99
		CN 1141859 A	05/02/97
		JP 9056126 A	25/02/97
		JP 8340663 A	24/12/96
FR 2630868 A1	03/11/89	NONE	
EP 0800951 A1	15/10/97	JP 9266601 A	07/10/97
		US 5973460 A	26/10/99
WO 9709191 A1	13/03/97	AU 6949196 A	27/03/97
		EP 0848671 A	24/06/98
		SE 505214 C	14/07/97
		SE 9503043 A	05/03/97

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 99/02276

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0743208 A2	20/11/96	CA 2195434 A	21/11/96
		EP 0743209 A	20/11/96
		EP 0743210 A	20/11/96
		EP 0743211 A	20/11/96
		EP 0743212 A	20/11/96
		EP 0743213 A	20/11/96
		EP 0743214 A	20/11/96
		EP 0743215 A	20/11/96
		EP 0743216 A	20/11/96
		EP 0743217 A	20/11/96
		EP 0775607 A	28/05/97
		JP 9042122 A	10/02/97
		JP 9046965 A	14/02/97
		JP 9046966 A	14/02/97
		JP 9046967 A	14/02/97
		JP 9047011 A	14/02/97
		JP 9047092 A	14/02/97
		JP 9047093 A	14/02/97
		JP 9047094 A	14/02/97
		JP 9047095 A	14/02/97
		JP 9047096 A	14/02/97
		JP 9175203 A	08/07/97
		US 5789877 A	04/08/98
		US 5804934 A	08/09/98
		US 5873801 A	23/02/99
		US 5903112 A	11/05/99
		US 5903113 A	11/05/99
		US 5905346 A	18/05/99
		US 5909094 A	01/06/99
		US 5920160 A	06/07/99
		US 5942862 A	24/08/99
		WO 9636507 A	21/11/96
EP 0769403 A2	23/04/97	JP 9170533 A	30/06/97
		US 5934395 A	10/08/99
DE 4324010 A1	19/01/95	NONE	

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 99/02276

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0917978 A2	26/05/99	CN 1225317 A	11/08/99
		CN 1225872 A	18/08/99
		CN 1226484 A	25/08/99
		CN 1226487 A	25/08/99
		EP 0917981 A	26/05/99
		EP 0917982 A	26/05/99
		EP 0921024 A	09/06/99
		JP 11234806 A	27/08/99
		JP 11234807 A	27/08/99
		JP 11243603 A	07/09/99
		JP 11252710 A	17/09/99
		NO 985417 A	25/05/99
		NO 985418 A	25/05/99
		NO 985419 A	25/05/99
		NO 985420 A	25/05/99
		PL 329781 A	24/05/99
		PL 329782 A	24/05/99
		PL 329783 A	24/05/99
		PL 329784 A	24/05/99
		US 5910722 A	08/06/99
		US 5929595 A	27/07/99
		US 5941328 A	24/08/99
EP 0754588 A1	22/01/97	JP 9037407 A	07/02/97
		US 5915801 A	29/06/99

THIS PAGE BLANK (USPTO)